# THE INFLUENCE OF SEVERAL CABLE-TYPE SUPPORTS UPON THE STATIC PRESSURES ALONG THE CENTERLINE TUBE IN A TRANSONIC WIND TUNNEL

By

Richard S. Dick; PWT, ARO, Inc.

February 1955

# ARNOLD ENGINEERING
# DEVELOPMENT CENTER

## AIR RESEARCH AND DEVELOPMENT COMMAND

US ✠ AF

# THE INFLUENCE OF SEVERAL CABLE-TYPE SUPPORTS UPON THE STATIC PRESSURES ALONG THE CENTERLINE TUBE IN A TRANSONIC WIND TUNNEL

By

Richard S. Dick; PWT, ARO, Inc.

February 1955

Contract No. AF 18(600)-1233

# CONTENTS

## TABLE 1

ILLUSTRATIONS

# SUMMARY

Tests were conducted in the Transonic Model Tunnel to determine the effect of 10 different cable-type support systems for a centerline tube on the static pressures measured on this centerline tube. These tests were conducted at Mach numbers from 0.80 to 1.30 and included varying the angle of sweep of the supporting wires, the wire size, and the method of attaching the wires to the centerline tube. The local Mach number distributions measured on the centerline tube, with and without these wire support systems, are presented, as well as the resultant errors in Mach number for the configuration showing the least disturbances.

The results indicate that the most desirable support system should utilize wires having a high degree of sweepback and should be attached to the centerline tube without any protruding fixtures. The data at the higher Mach numbers indicate that the intensity and extent of the disturbances may tend to build up downstream of the support and become serious on wires swept back at the Mach angle.

# INTRODUCTION

Static-pressure measurements in the test section where the model will be mounted are essential to the calibration of every wind tunnel. One of the most reliable and accurate methods of measuring these static pressures is with an axial static-pressure tube. These axial tubes usually extend from the subsonic region upstream of the test section and nozzle to a region downstream of the test section.

Early in the design phase of an axial static-pressure tube for the calibration of the Transonic Circuit of the Propulsion Wind Tunnel (PWT) it became apparent that this tube would have to have a center support because of its great length and relatively small diameter. This support is a structural necessity and in the Transonic Circuit will be located in the forward portion of the test section. In the test conducted in the Transonic Model Tunnel, the support was attached at the 19-in. station because large Mach number gradients exist just downstream of the end of the nozzle at the higher Mach numbers. Since no information could be found to show the effect of the support system contemplated, the decision was made to conduct tests in the Transonic Model Tunnel (TMT) to determine how three support wires attached to the tube would affect the static pressures measured on the tube and to determine what the optimum configuration would be.

The TMT is a 1/16-scale model of the nozzle, test section, and diffuser of the Transonic Circuit of the PWT. For these tests, the tunnel walls were fitted with a set of transonic liners.

## TESTS AND APPARATUS

The wire-support system chosen for use throughout the test program consisted of three wires attached to a 1-in. diameter centerline tube at the 19-in. station and extending to the tunnel walls. A typical installation in the 12-in. square test section is shown in Fig. 2. This general arrangement was selected because it provided a minimum length of cable in the airstream and did not introduce any moments into the centerline tube. In the PWT, the wire-support system will be attached to the centerline tube in the forward portion of the test section. However, in these tests the point of attachment was moved into the center of the test section because in the TMT large Mach number gradients exist just downstream of the end of the nozzle at the higher Mach numbers.

The test program included varying the angle of sweep of the supporting wires from -45° (swept forward) to +60° (swept back) and changing the diameter of the wires from 0.030 in. to 0.083 in. while using either a flush or circular-arc attachment fixture (Fig. 1). The tunnel Mach number distribution measured on the centerline tube without a wire-support system is shown in Fig. 3. The 10 support configurations tested are tabulated in Table 1. Static pressures were obtained on the top of the centerline tube with and without the wire-support systems at Mach numbers from 0.80 to 1.30. Since these tests were conducted in two phases and between these two phases a new centerline tube with additional orifices was installed in the tunnel, the data presented differ in orifice spacings.

## RESULTS AND DISCUSSION

The original thinking on this investigation was that since the shock waves would be relatively weak at low supersonic Mach numbers, the local influence caused by the size of the wire and the method of attaching the wire to the tube would predominate. Thus the centerline tube, attachment fixture, and wire diameter should all be to the same scale, but not necessarily the same scale as the tunnel. Inasmuch as the existing TMT centerline tube was a 1/6-scale model of that to be used in the PWT, a wire diameter of 0.083 in. was established (simulating a 1/2-in. cable in the PWT), and the external fixtures were made to a corresponding size.

In the early phase of testing, the data indicated that the original assumption that the local influence of the wire and attachment fixture would predominate was erroneous. The data indicated that strong disturbances originating from the 1/6-scale configurations were affecting the static pressures well downstream of the point of attachment. In an effort to establish more accurately to what extent these disturbances would affect the static pressures measured on the centerline tube in the PWT, the wire diameter was reduced to 0.030 in., which is 1/16-scale of the 1/2-in. cable to be used in the PWT, and it was assumed that the oversized axial tube did not affect the results. Since the initial series of tests also indicated that the method used in attaching the wires to the cables was secondary to the angle of sweep, no tests were made using the wire of smaller diameter in conjunction with the external circular-arc attachment fixtures.

The results are presented in Figs. 4 to 13 in the form of the local Mach number distributions as calculated from the static pressures measured on the centerline tube. The dotted lines labeled "Wire-Wall Intersection" shown on

Figs. 4 to 12 indicate the position at which disturbances originating at the intersection of the wire and the wall would theoretically intersect the centerline of the tunnel. Similarly the solid lines labeled "Wire-Tube Intersection" represent the positions at which disturbances originating at the intersection of the wire and the tube would be reflected back to the centerline of the tunnel from a solid wall. The dotted lines labeled $M_c$ on Figs. 4 to 13 show the Mach number corresponding to the plenum-chamber pressure for each case. It should be noted that there is a tendency for some of these curves either to rise or fall off at the end of the test section as a result of excess or insufficient pressure ratio during the test and, therefore, this rising or falling of the curve should not be attributed to the test configuration. The errors in calculated Mach number for the vicinity affected by the wire system are regarded as being less than 0.25 percent for all configurations. Although certain individual points indicate larger possible errors, these generally occur in the forward portion of the test section where the flow is expanding to supersonic velocities and is very sensitive to the chamber pressure.

EFFECT OF SWEEP

During the tests conducted to determine the optimum configuration for a center support for the axial static-pressure tube, the effect of sweeping the wires was investigated more thoroughly than the other parameters. The effect of sweep was investigated using both wire sizes and with the circular-arc attachment fixture in combination with the larger wire size. The five degrees of sweep selected and tested were $-45^\circ$, $0^\circ$, $30^\circ$, $45^\circ$, and $60^\circ$. These angles were chosen arbitrarily. The results of these tests are presented in Figs. 4 through 10.

The results of these tests indicate that sweeping the wires has a pronounced

effect on the static pressures measured on this tube, and the resultant errors in Mach number also are pronounced. It can be readily seen that a very large disturbance exists when the wire is normal to the stream (Fig. 4), and that the intensity of these disturbances is reduced somewhat when the wire is swept forward at 45° (Fig. 6). The normal and sweptforward configurations are entirely unsatisfactory, but the more highly sweptback configurations provide a more satisfactory method of support. It will be noted that at the lower Mach numbers the area affected by the sweptback wires is at the junction of the wire and the tube. As the Mach number is increased above 1.0, the area affected moves downstream, and the intensity of the disturbances becomes greater (Fig. 5).

It might be expected that as the sweep angle approaches the Mach angle for any particular Mach number, the disturbance which was generally dispersed throughout the test section would tend to build up along the wire and reflect back onto the axial tube with relatively high intensity. At Mach numbers other than those corresponding to the Mach angle, these disturbances would tend to dissipate. In these tests this buildup would occur at M = 1.15 for the 30° sweptback configuration, at M = 1.40 for the 45° sweptback configuration, and at M = 2.00 for the 60° sweptback configuration. At M = 1.15 and with a 30° sweptback configuration, no indication of this phenomena is apparent. For the 45° sweptback configurations (Figs. 5 and 9), a large disturbance is apparent downstream of the wire at M = 1.30 near the point at which such a buildup would occur, and it is entirely possible that this disturbance is the result of such a buildup. Since 60° is the Mach angle for M = 2.00, it would not be expected that any buildup would be indicated in the scope of these tests. It might be noted that at M = 1.30 the velocity component normal to the wire is M = 1.12 for the wire swept back 30°,

M = 0.92 for the wire swept back 45°, and M = 0.65 for the wire swept back 60°.

Inasmuch as configuration G (Fig. 10: 0.030-in. wire diameter, flush attachment fixtures and swept back 60°) proved to be the most satisfactory method of supporting the center of the axial tube and caused the least disturbance in the test section, the local Mach number distributions obtained on the centerline tube have been replotted in Fig. 14 in terms of the parameter

$$( \frac{M_c - M_L}{M_c} ) - ( \frac{M_c - M_L}{M_c} )_{Calib} .$$

The subscripts c and L in this parameter refer to the plenum chamber and local conditions respectively. The subscript Calib. refers to the tunnel-empty calibration values shown in Fig. 3. This term when multiplied by 100 will give the percentage error in Mach number. Although an overall error is indicated upstream of the point of attachment on the data shown in Fig. 14, this error is not a result of the test configuration but results from relatively poor correlation of the chamber pressures in the test and calibration runs. It will be noted that the maximum error in Mach number caused by the presence of the wires is less than 1 percent throughout the Mach number range investigated.

EFFECT OF THE METHOD OF ATTACHMENT

Included in the wire-interference program were several tests to determine the effect of the method used in attaching the wire to the axial tube. These tests were conducted with the wires normal and swept back 45° to the airstream, utilizing both a flush and a protruding circular-arc attachment system. The flush-support system consisted of attaching the wires to the axial tube with no external fixtures, whereas the protruded system consisted of attaching the wires to the circular-arc fixture, which was in turn attached to the axial tube. This attachment

fixture was selected so as to give relatively clean aerodynamic shape and still supply the mechanical designer with some method of externally attaching the wire to the tube.

The static pressures measured on the axial tube are shown in Figs. 4, 5, 11, and 12 for configurations A, B, H, and I respectively. The only apparent effect of using an external attachment was to magnify the disturbances in the immediate area of the attachment. At all Mach numbers the effect of the attachment on the static pressures measured downstream of this attachment appears to be obscured by the more influential wire disturbances. It may be stated generally that within the scope of these tests the effect of this type of attachment on the pressures measured on the axial tube is small compared with the wire disturbance.

EFFECT OF SUPPORT WIRE SIZE

To obtain a better indication of what the intensity of the disturbance will be in the PWT, the wire diameter was reduced from 0.083 in. to 0.030 in., thus keeping the ratio of tunnel size to wire size a constant, and more nearly approximating the true strength of the disturbance. Since the most desirable configuration tested in the larger wire size had utilized a flush mount and swept wires, the decision was made to use these configurations also with the small wire size. In doing this, data were also made available to show the effect of wire size on the disturbances at -45° and 45° sweep angles. (It may be noted that the 0.083-in. wire size, if considered as 1/16-scale, simulated cables 1.3 in. in diameter in the PWT.)

Figures 5, 6, 7, and 9 show that the intensity and length of the disturbances were reduced considerably throughout the Mach number range when the wire diameter was reduced. The smaller wires, when combined with a high degree

of sweep, appear to give disturbances which are acceptable throughout most of the Mach number range investigated.

SPECIAL TEST

In conjunction with these wire interference tests, a configuration was tested which is identical to that now in use at WADC on sections of the tube to be used in the PWT. In the WADC installation these supports are not in the testing region; however, in the PWT installation these supports would be in the rear of the test section. This configuration was tested using a 1/6-scale model of the wire, attachment fixture, and tube. The configuration differed from the others in that the attachment fixture was larger and had a rectangular shape (see Fig. 1) and that the top wire was located 6-in. upstream of the other two wires which were still attached at station 19.

The data from this configuration are presented in Fig. 13. This figure shows that this system created large disturbances downstream of the first wire; however, because of the length of the test section of the model tunnel it is impossible to determine how far downstream these disturbances existed. Inasmuch as the downstream end of the tube is no longer to be supported by wires and no moment is desired at the center support, the results of these tests are no longer applicable to the problem at hand.

# CONCLUSIONS

The tests of the various axial static-pressure tube support systems indicated that support wires having a normal, negative, or low sweepback angle produced undesirable pressure disturbances. However, a 1/16-scale model of a 1/2-in. cable swept back at $60^{\circ}$ and attached to the axial tube without any protruding fixtures produced disturbances acceptably small for use in the PWT Transonic Circuit up to a Mach number of 1.3. Since $60^{\circ}$ is the Mach angle for M = 2.00, and no build up of the disturbances would be expected until that Mach number is approached, the $60^{\circ}$ sweptback support system should give satisfactory results over the entire Mach number range of the Transonic Circuit from M = 0.80 to 1.60.

# TABLE 1

## CONFIGURATIONS TESTED

| Configuration | Wire Diam. (Inches) | Sweep (Deg) | Attachment Fixture |
|---|---|---|---|
| A | 0.083 | 0 | Flush |
| B | 0.083 | 45 | Flush |
| C | 0.083 | -45 | Flush |
| D | 0.030 | -45 | Flush |
| E | 0.030 | 30 | Flush |
| F | 0.030 | 45 | Flush |
| G | 0.030 | 60 | Flush |
| H | 0.083 | 0 | Circular arc |
| I | 0.083 | 45 | Circular arc |
| J | 0.083 | 0 | Rectangular (special) |

NOTE: All wires were attached to the axial tube at a point 19-in. downstream of the end of the nozzle with the exception of configuration J. Two of the wires used in configuration J were attached at station 19 and one at a point 6-in. upstream of this point.
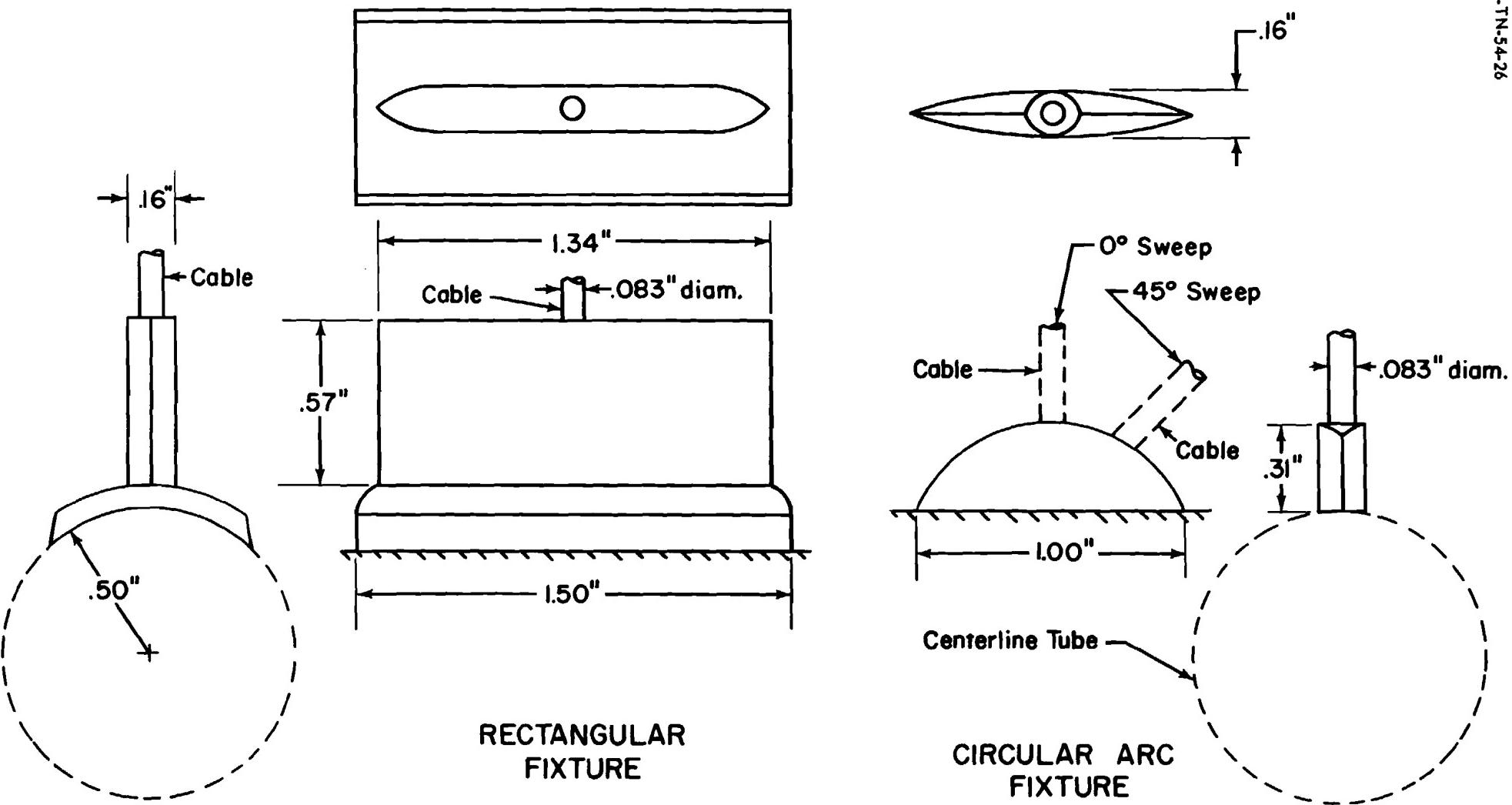
Fig. 1.  Details of Fixtures Used to Attach the Wire to the Centerline Static Pressure Tube

TEST SECTION 37.5"

19"

A

FLOW

CENTERLINE
TUBE

A

12"

12"

1" DIAM
TUBE

WIRE

SECTION A-A
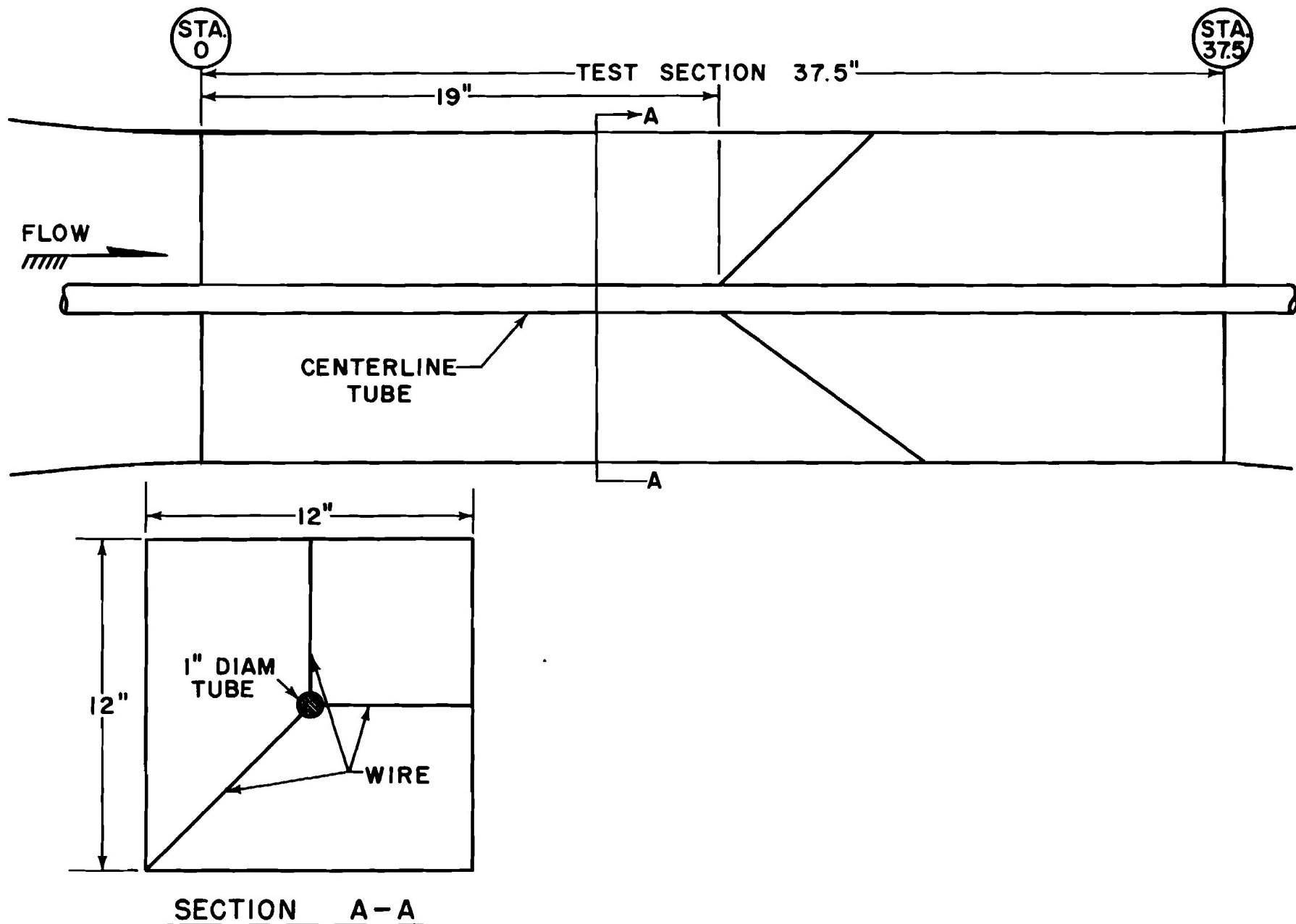
Fig. 2. A Typical Cable-Support Test Configuration in the Transonic Model Tunnel
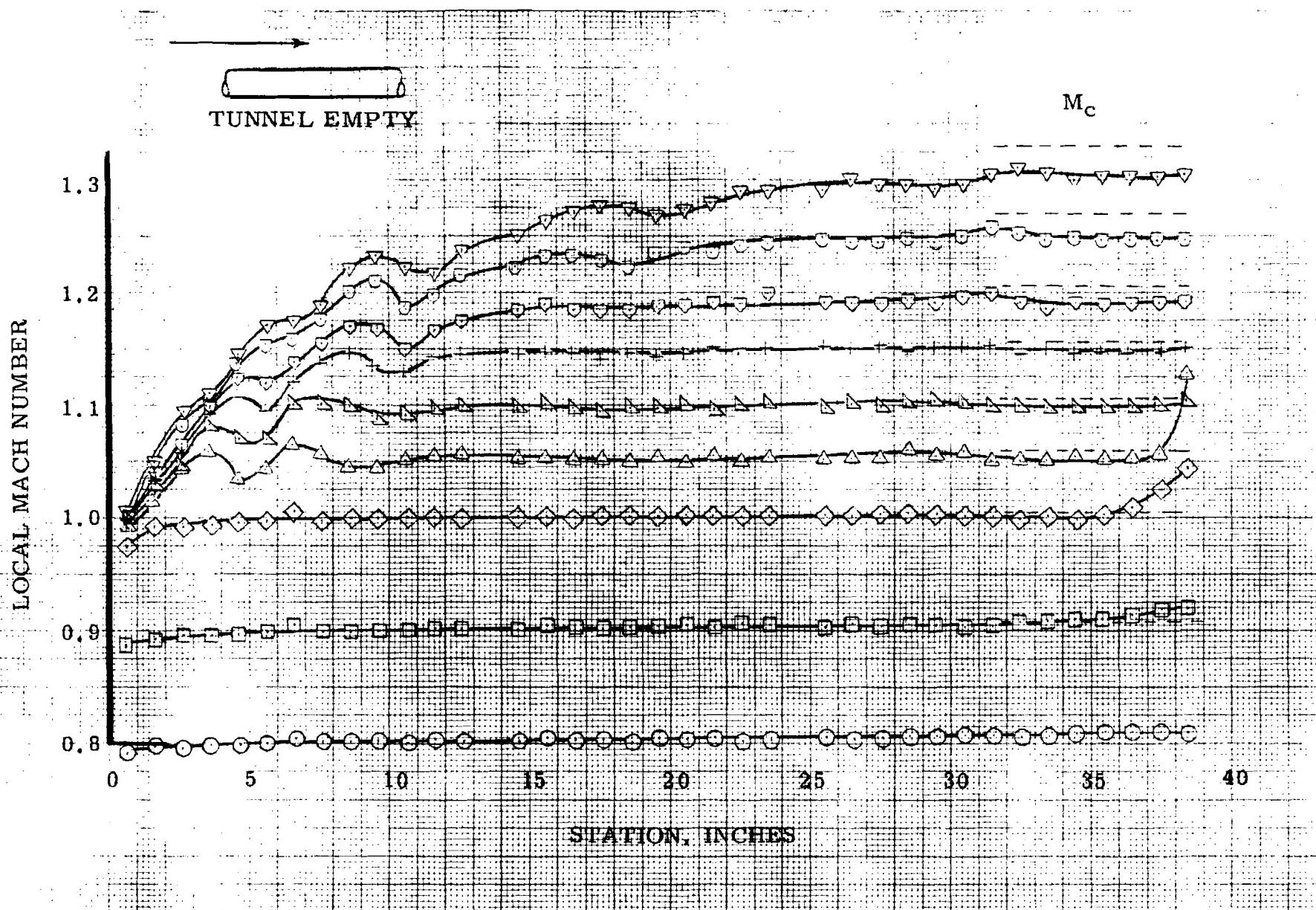
Fig. 3. Local Mach Number Distribution on the Centerline of the Tunnel with No Wire-Support Configuration (Transonic Wall Liners)
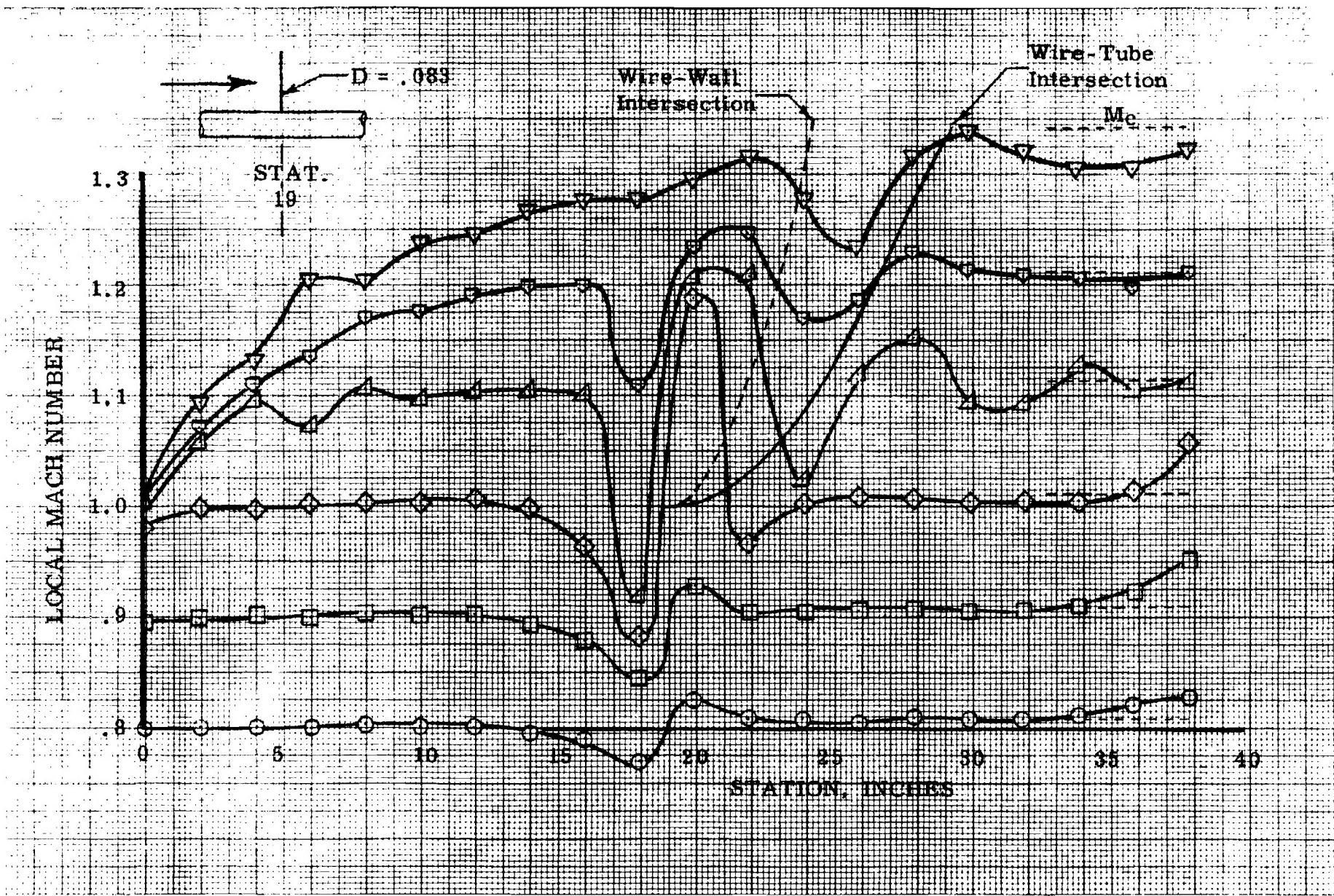
Fig. 4.  Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration A
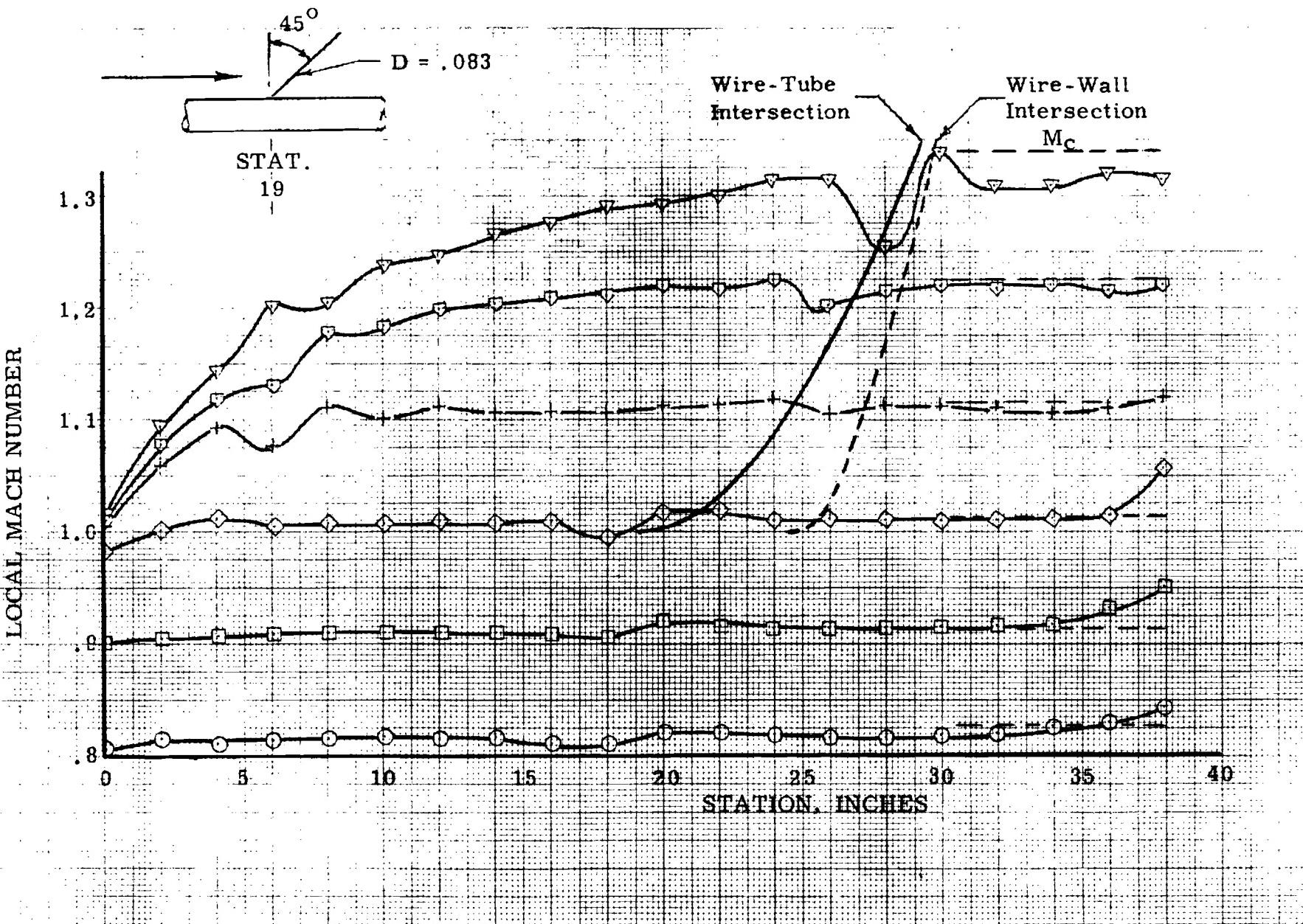
Fig. 5. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration B
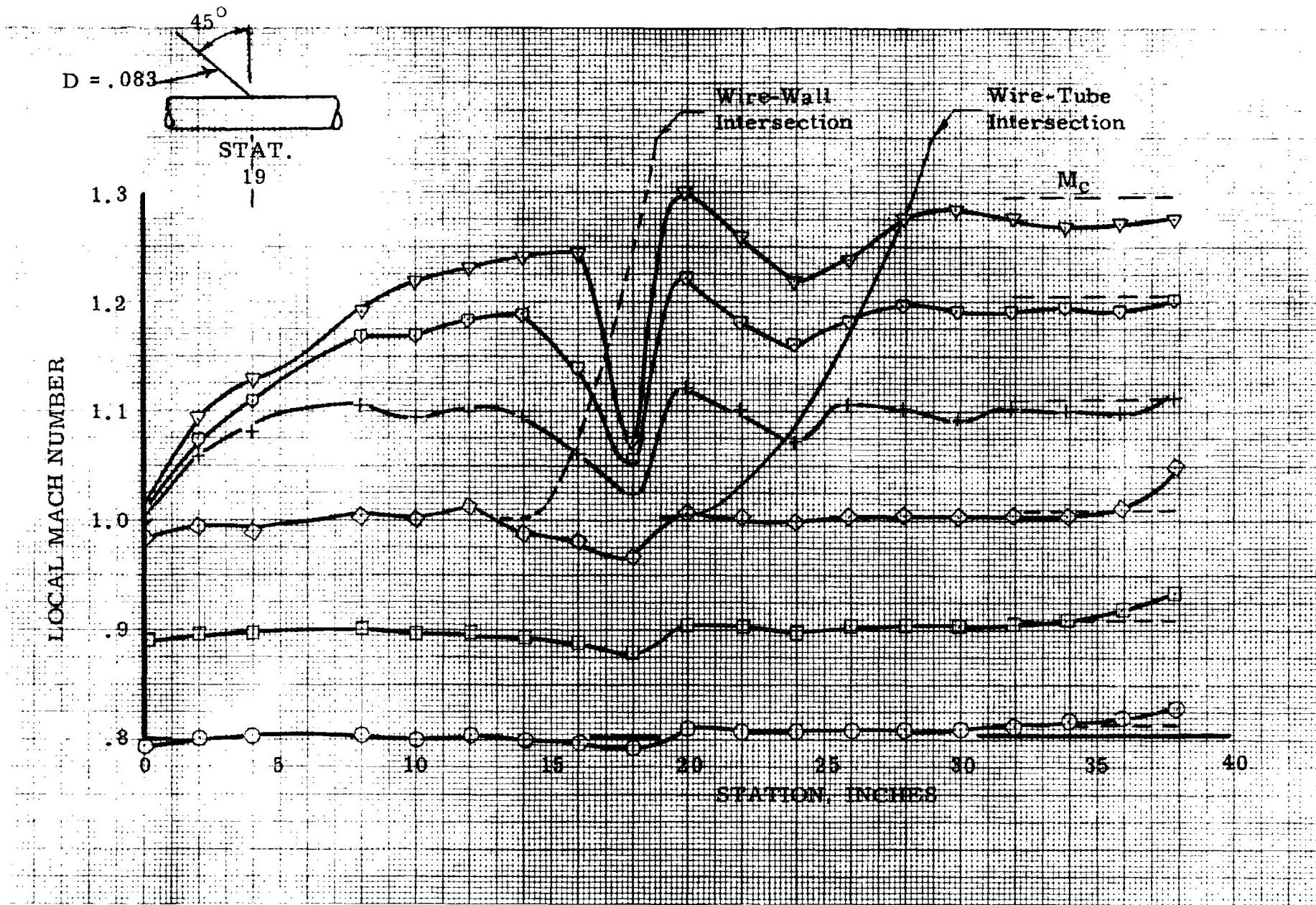
Fig. 6. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration C
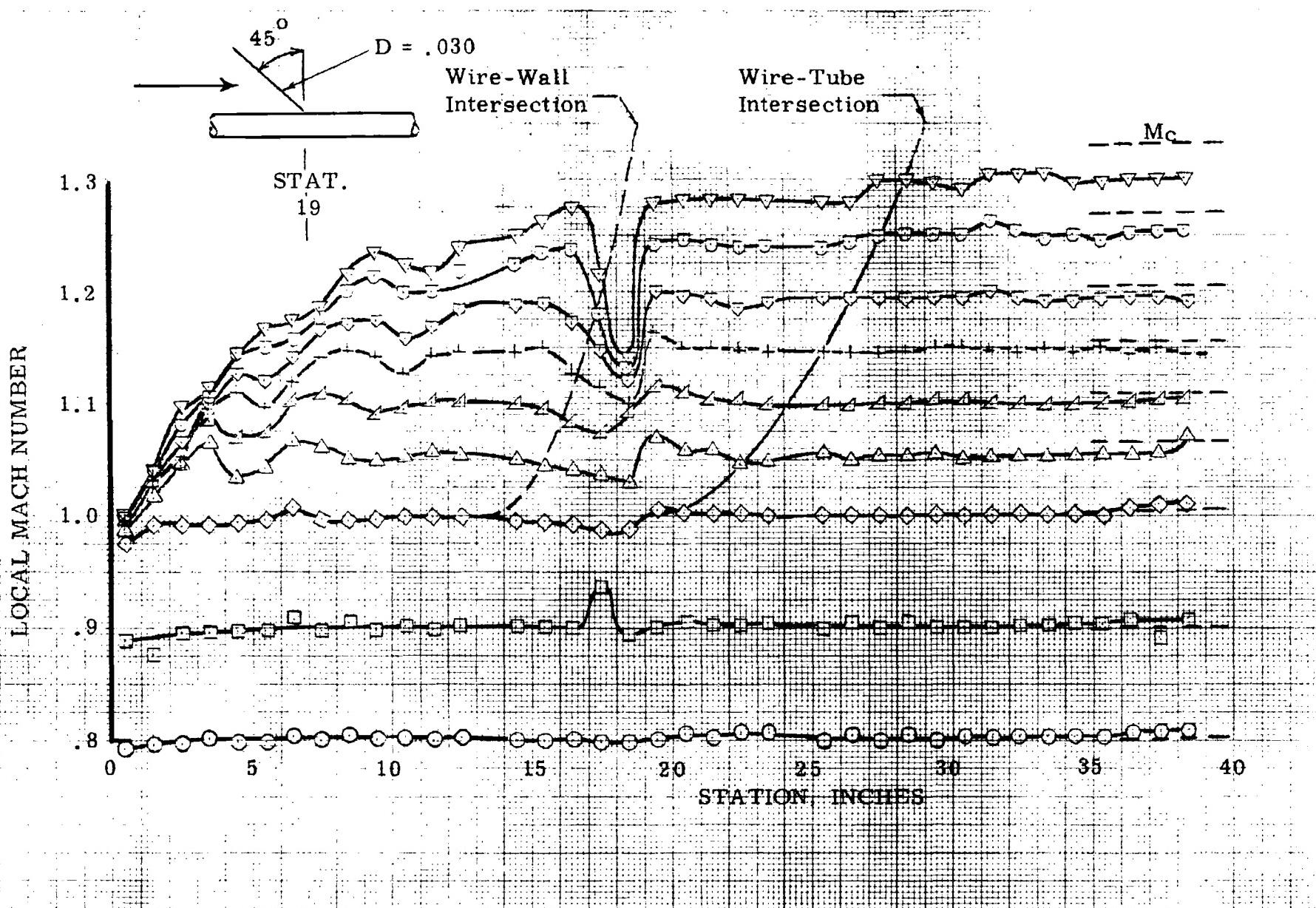
Fig. 7. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration D
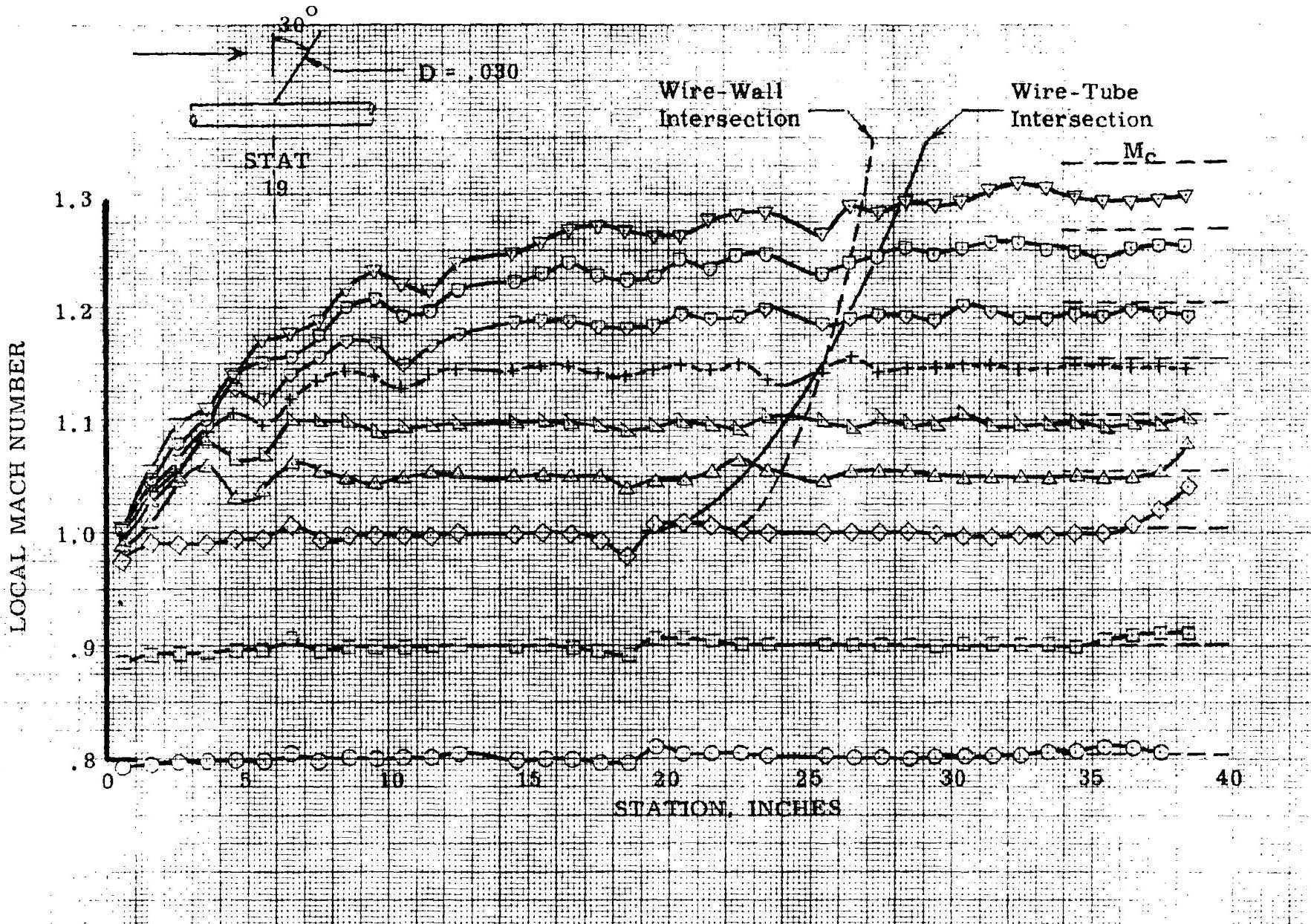
Fig. 8. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration E
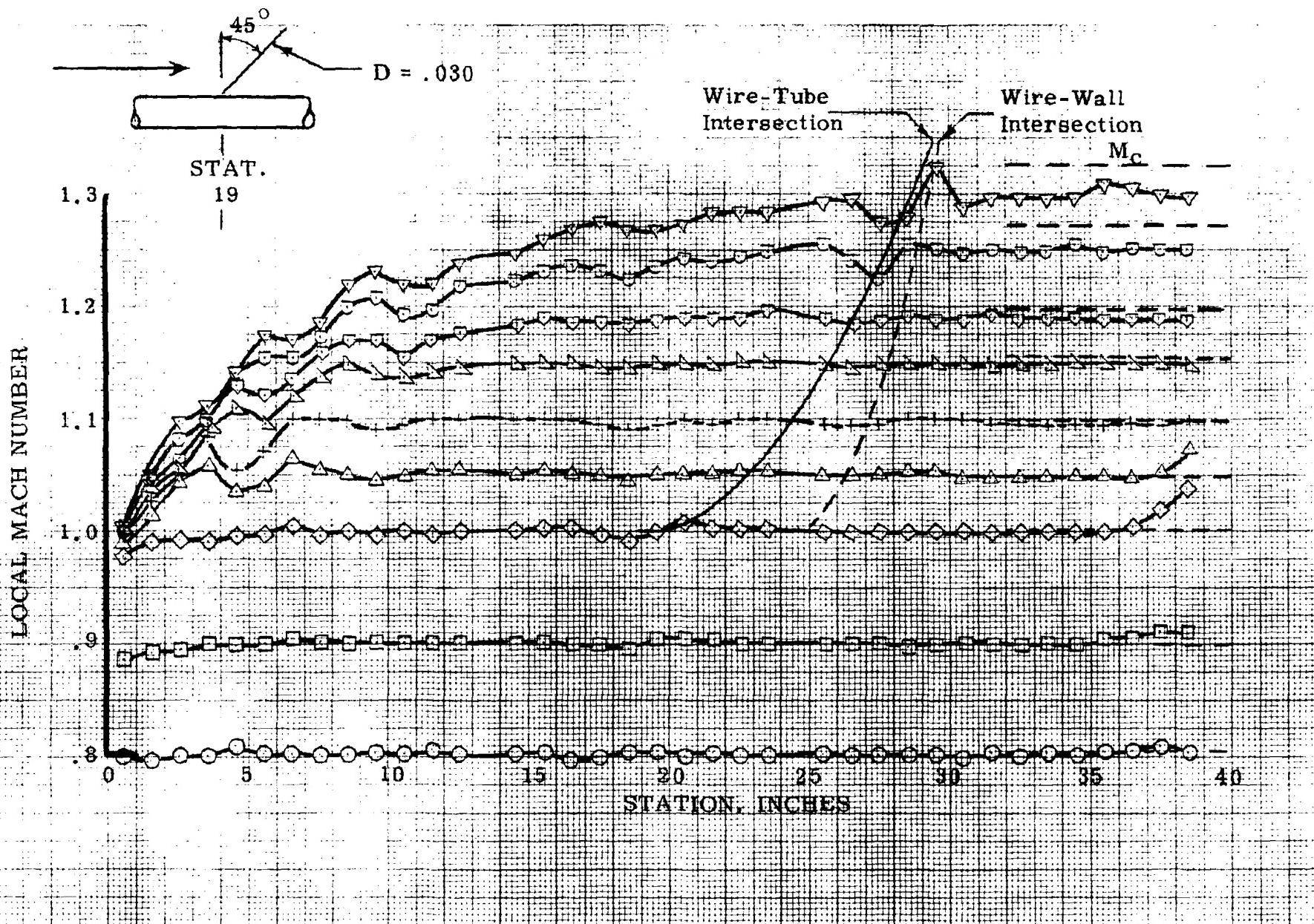
Fig. 9. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration F
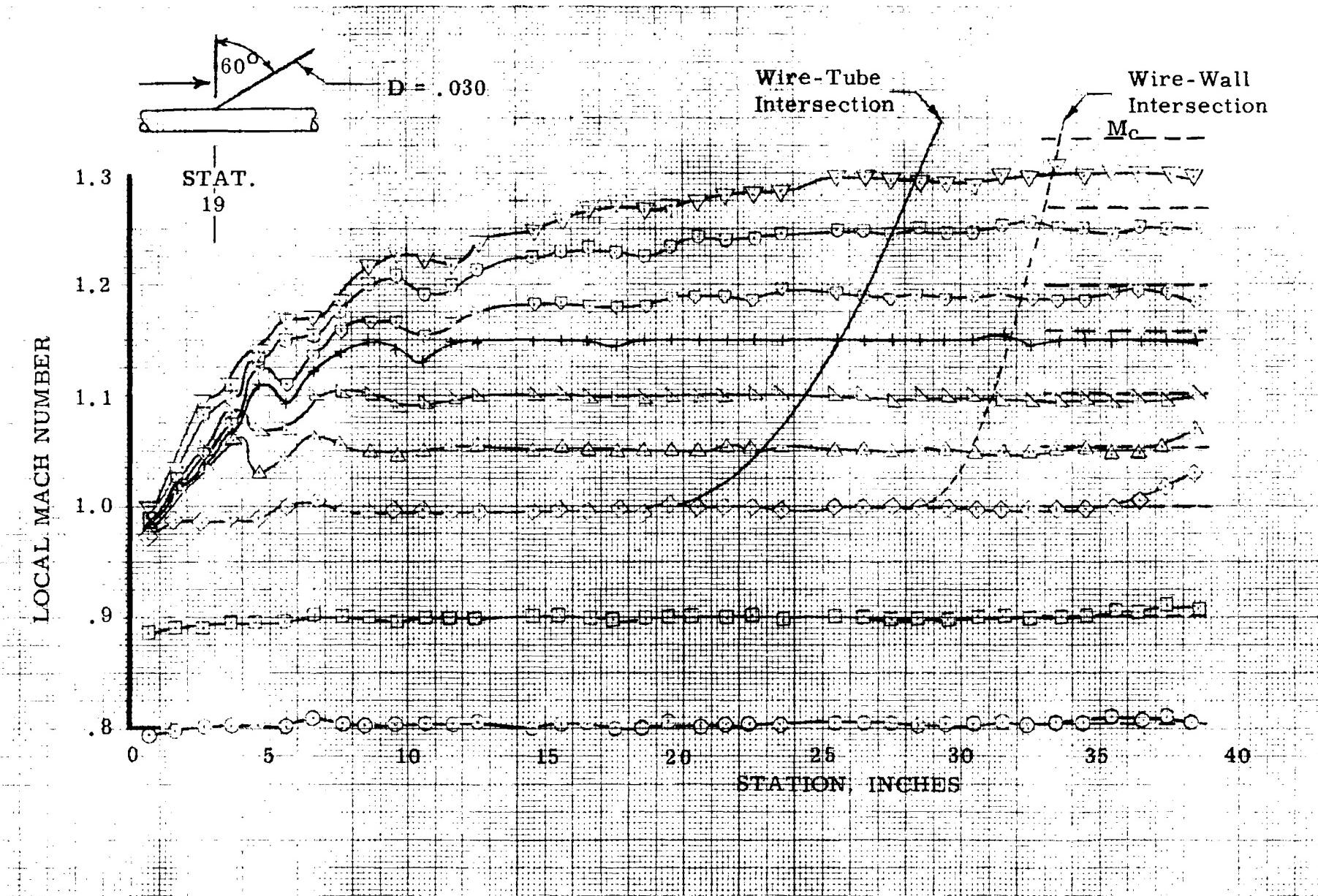
Fig. 10. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration G
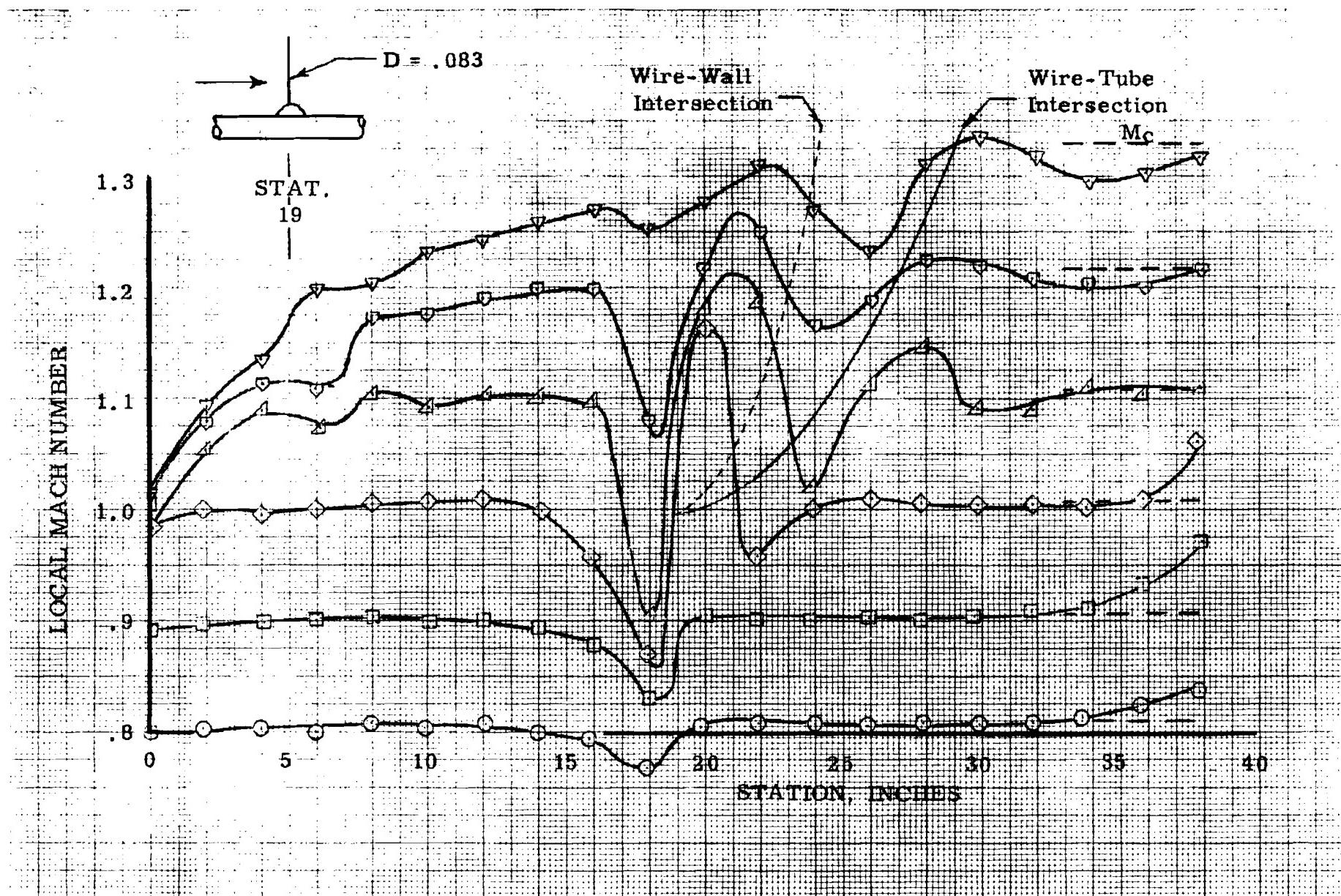
Fig. 11. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration H
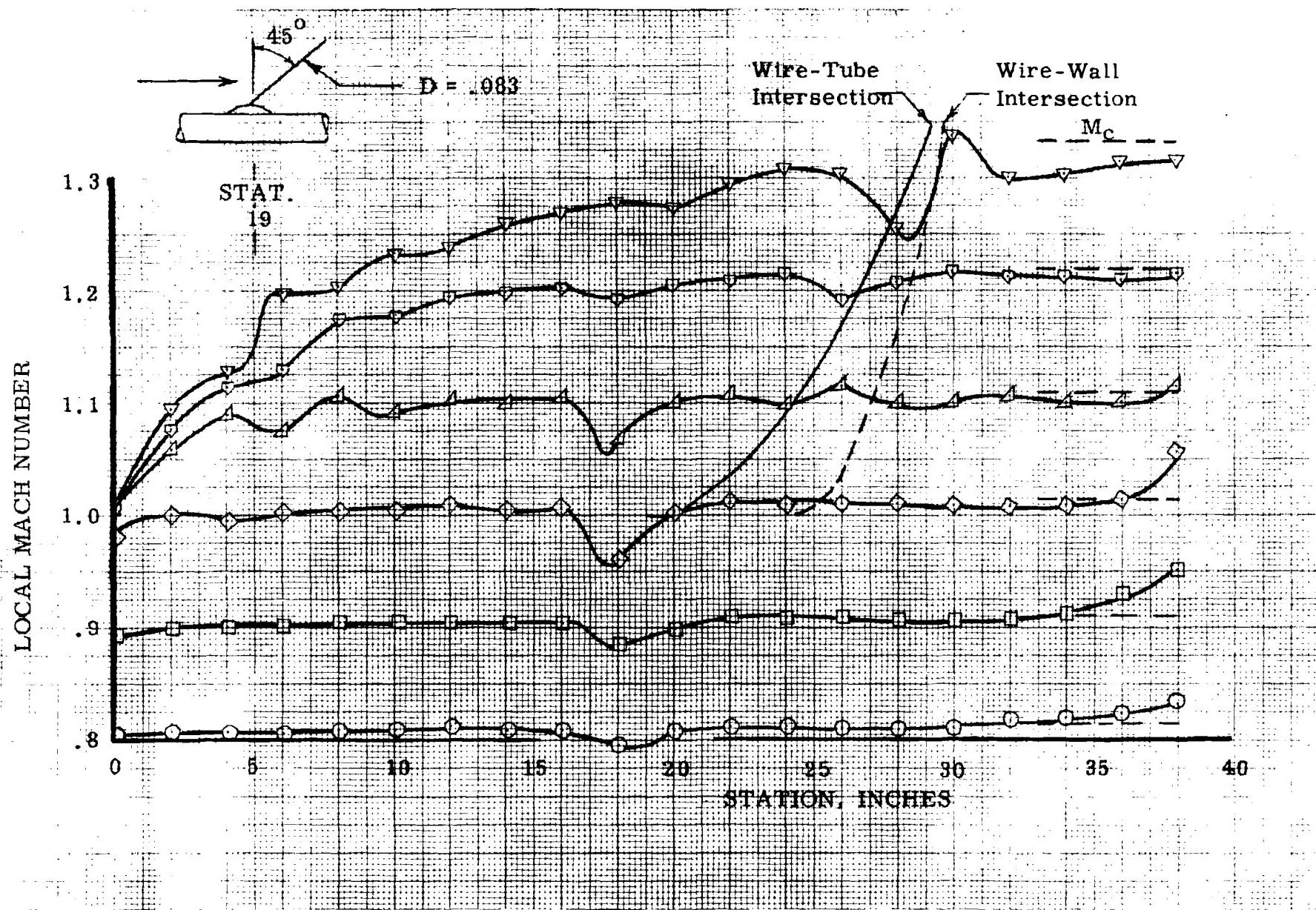
Fig. 12. Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration I
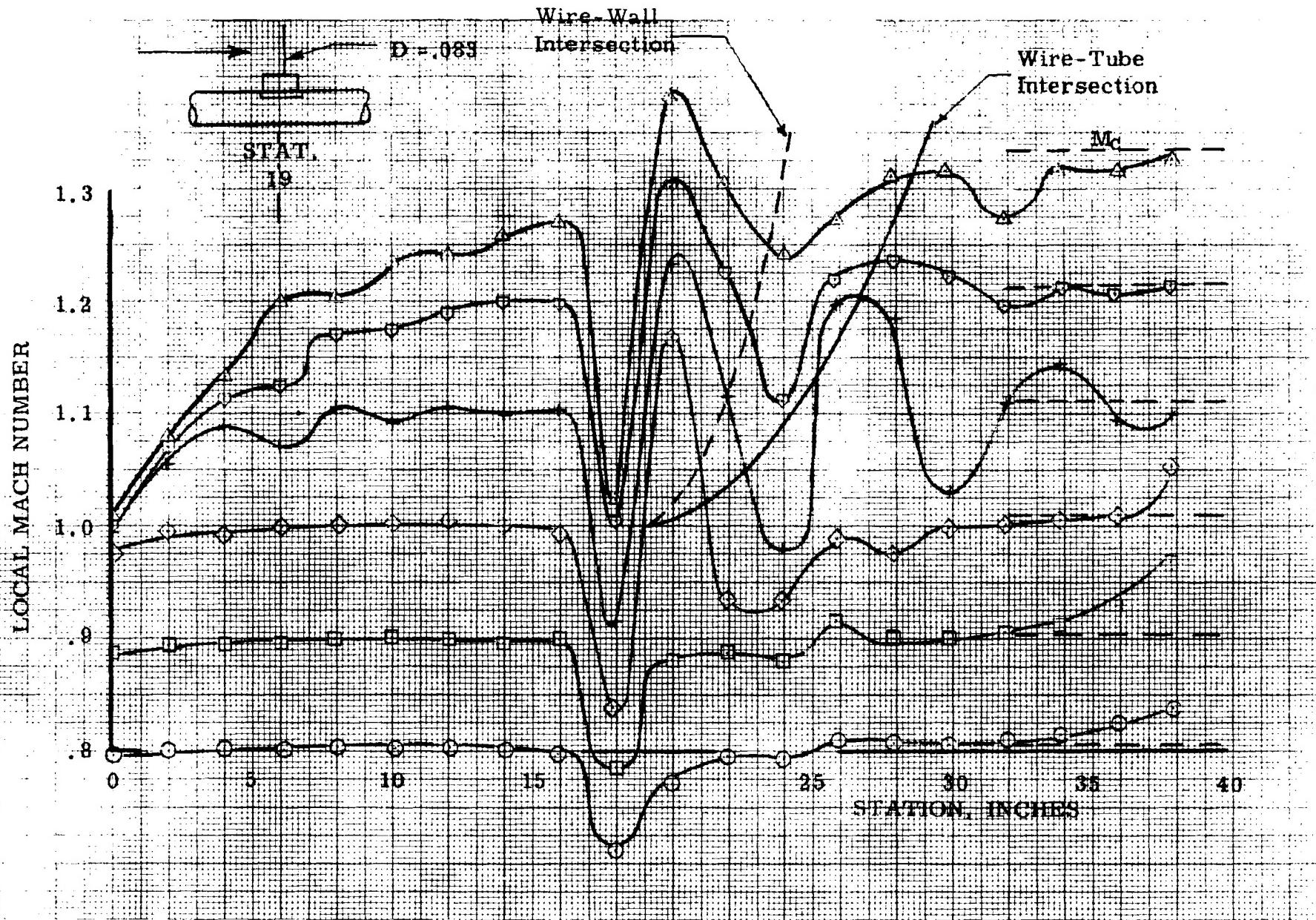
Fig. 13.  Local Mach Number Distribution on the Centerline of the Tunnel with Wire-Support Configuration J
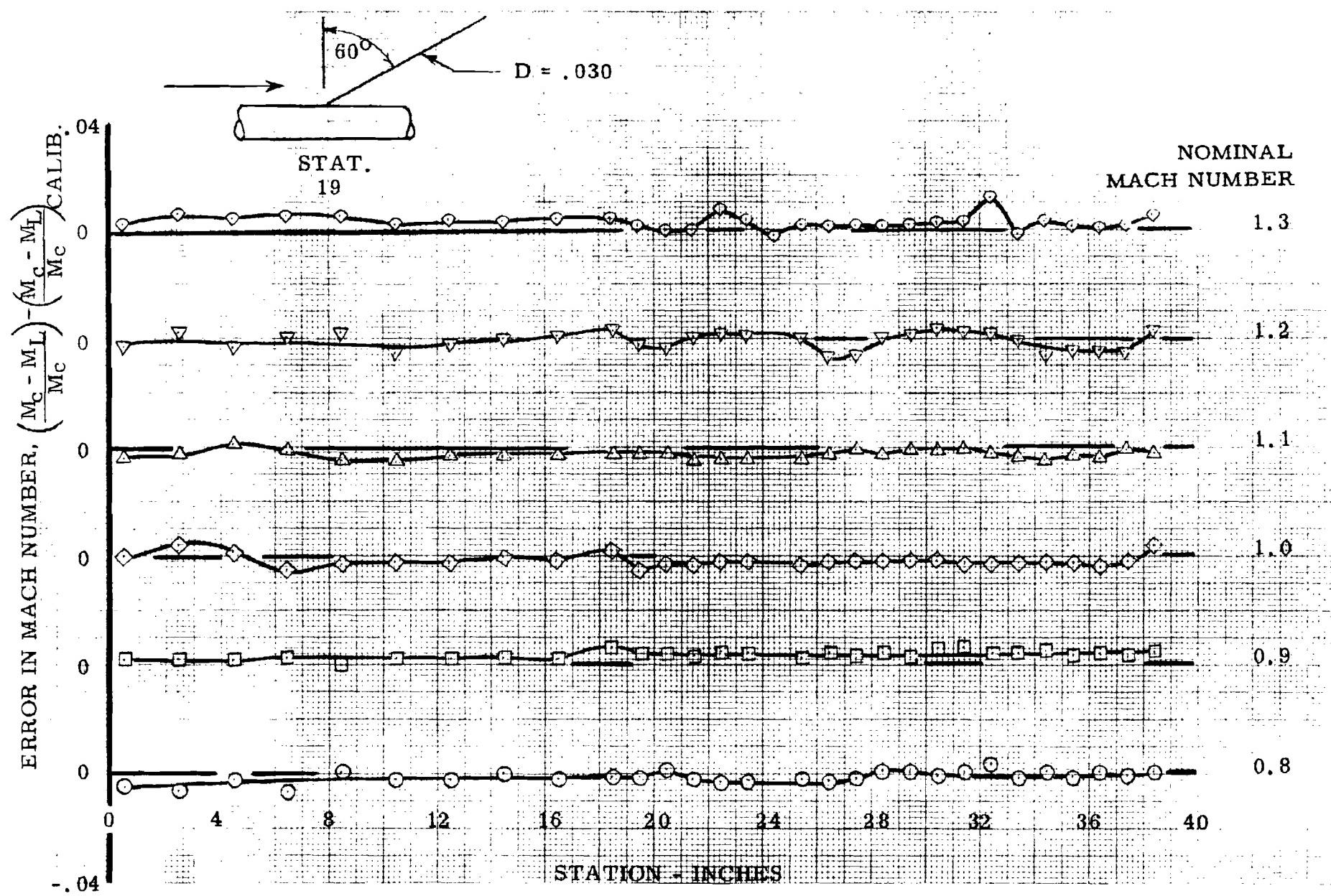
Fig. 14. Error in the Local Mach Number Measured on the Centerline of the Tunnel with a Satisfactory Wire-Support Configuration (G)